Landsat Data Continuity Mission

HQ Actions/Issues

January 8, 2008

Topics

- Introduction/Overview
- LDCM Draft Level – 1 Requirements changes
  - Requirements review process and results
- Potential Directed Instrument Manifests
  - Total Solar Irradiance Sensor (TSIS)
  - Thermal Infrared Radiometer Sensor (TIRS)
- Conclusion/Actions

Introduction/Overview

LDCM schedule is driven by need to minimize data gap with Landsat 7

NET July 2011 LRD and L-5/7 fuel depletion in 2010 = 6-12 month data gap

Schedule driver has resulted in “aggressive” instrument schedule

- **40 mo vs. 60 mo typical**

Aggressive Instrument Schedule driving OLI Development Risk

Ball implementation “out-of-phase” with typical development

- Procurements of major components in-place and many deliveries expected before Critical Design complete

Schedule Risk accepted with Contract award

Risk highlighted at Source Selection Decision briefing

- 6-month schedule risk identified

SMD AA requested “requirements analysis” to determine options for potential risk reduction/mitigation

Requested legal compliance correlation to performance and

Areas/ideas to reduce schedule driving performance requirements

LDCM Draft Level – 1 Requirements

#	Band	Minimum Lower Band Edge (nm)	Maximum Upper Band Edge (nm)	Center Wavelength (nm)	Maximum Spatial Resolution At Nadir (m)
1	Coastal /Aerosol	433	453	443	30
2	Blue	450	515	482	30
3	Green	525	600	562	30
4	Red	630	680	655	30
5	NIR	845	885	865	30
6	SWIR 1	1560	1660	1610	30
7	SWIR 2	2100	2300	2200	30
8	Panchromatic	500	680	590	15
9	Cirrus	1360	1390	1375	30
10*	Thermal 1	10300	11300	10800	120
11*	Thermal 2	11500	12500	12000	120

To Be Removed

* Contingent upon funding, and requirement trades between program elements, technical requirements, and mission risk as part of the LDCM procurement.

Requirements Review Process

Actions:

1) Analyze performance requirements for LDCM that are required by law

2) Prepare a list of potential schedule risk mitigation actions for the Operational Land Imager that would simplify the instrument development but keep the performance required by the law

Approach:

ESD engaged the EOS Program Office with the following course of action:

- Identify the legal and policy functional and performance requirements for the mission
- Trace the legal and policy requirements of "continuity" to OLI
- Identify the variances and document the justification for the variance,
- Analyze the risk (technical, cost, schedule, programmatic and political) associated with each item, and document the results for review.

Expected Outcome

A rigorous analysis of the “development impact” for every identifiable actions:

- Trace impact of action from requirement, to design, to fabrication, to integration, to test, to acceptance and through to operations
- Develop a tailored Government process and procedure including contractor oversight and interaction

Requirements Review Process

The 1992 Landsat Policy Act directs Landsat Program Management to study options for a successor mission to Landsat 7 that maintains data continuity:

> Continuity is defined as “data sufficiently consistent (in terms of: acquisition geometry, coverage characteristics, and spectral characteristics) with previous Landsat data to allow comparisons for global and regional change detection and characterization”

Change detection requires sufficient consistency with Landsat 7:

> **Acquisition geometry**: synoptic field of view (185 km swath); comparable spatial resolution (30 m multispectral, 15 m pan); geolocated, conformal imagery (65 m accuracy, band-to-band registration)
>
> **Coverage characteristics**: seasonal coverage of the global land mass including coastal (400 scenes per day)
>
> **Spectral characteristics**: multispectral coverage of the visible, near-infrared, shortwave infrared, thermal infrared; radiometric calibration (5% accuracy); spatial and temporal radiometric stability

Requirements Review Process

Option	Science Impact	Assessment	Risk	Critical Path ROM
Refine Testing	None	Cal/Val team interaction with BATC.	Low: primarily redundancy elimination and acceptable reduction	**TBR day decrease to critical path**
Eliminate on-orbit SNR incentive	None	SNR incentive Driving Yield Requirements.	Provides up to 10 weeks of schedule risk mitigation **Elimination frees up $1.2M to be reallocated**	**No critical path savings**
Eliminate pixel-to-pixel uniformity incentive	None	PPU performance limited by filter and detector technology	Provides up to 10 weeks of schedule risk mitigation **Elimination frees up $1.2M to be reallocated**	**No critical path savings**
Eliminate radiometric stability incentives and Relax requirements	Relaxation of cirrus band has minimal impact on science	Cirrus band stability need not be as stringent as other bands; can be relaxed with minimal science impact.	Provides up to 9 weeks of schedule risk mitigation **Elimination frees up $1.2M to be reallocated**	**No critical path savings**
Relax Mission Assurance Requirements	None unless sensor degrades or fails	GSFC Code 300 working with project to reduce compliance requirements		**No critical path savings**
Reduce CDRL items	None	CDRLs were well scrubbed prior to RFP release. A small number of efficiencies found in CDRLs.		**No critical path savings**
Relax pixel-to-pixel uniformity requirements	Some relaxation can be tolerated	Relaxation likely reduces requirement below ETM+ performance...	Provides up to 4 weeks of schedule risk mitigation	**No critical path savings**

Potential Directed Instrument Manifests

Total Solar Irradiance Sensor (TSIS)

De-manifest of capability from NPOESS - OSTP chartered continuity study (NOAA led)

- Study identified LDCM as potential near-term gap-filler platform
- Initiated vendor (LASP) accommodation study to reduce risk
- Included in spacecraft accommodation studies
- Final spacecraft RFO includes TSIS accommodation through design and as option for implementation
- **Manifest remains unauthorized and TBD**

Thermal Infrared Radiometer Sensor (TIRS)

- Removed from baseline in 2002 - determined to be not commercially viable
- NPOESS OLI: Technical (volume and mass) and budget constrained manifest
- Currently, budget profile cannot support development
- Following 2005 OSTP re-direction, user community lobbying increased and stakeholder inquiries escalated
- Congressional interest manifested in draft NASA 2008 appropriations language
  - The term “thermal” missing from final appropriation-now reads: “…data continuity…”

Final spacecraft RFO includes TIR accommodation through design and as option for implementation: **Manifest remains unauthorized and TBD**

Potential threat to LRD: 12-months currently, but will increase

Conclusion

- Baseline Mission (OLI-only) currently on-track for July 2011 LRD
- Requirements driver reviews conducted to mitigate OLI development risk
- TSIS and TIRS manifest unauthorized
  - Initiated risk mitigation
    - TIRS Instrument Team Study completed
    - Accommodation studies completed
    - Inclusion in s/c design and options for implementation
  - Potential threat to mission LRD due to TIRS development schedule

BACK-UP

Implementation Roles and Responsibilities NASA

Lead the mission development

- Mission-level systems engineering

Develop the LDCM Space Segment

- Instrument, Spacecraft and Launch Vehicle procurements
- Satellite integration and launch

Procure the Mission Operations Element for the USGS

- Command & Control, Scheduling, Long-Term Trending/Analysis, and Flight Dynamics capabilities
- Support for Observatory I&T/Launch Site
- On-Orbit Sustaining Engineering

Lead the pre-launch and orbital verification, calibration, validation and characterization

Manage on-orbit checkout of the LDCM system

Transfer the LDCM instrument and mission operations contract to DOI/USGS following on-orbit check-out and acceptance

After launch and on-orbit acceptance, support DOI/USGS with calibration, validation, and instrument characterization

Provide scientific and technical support for the Landsat Science Team

Support DOI/USGS operations anomaly investigations

Implementation Roles and Responsibilities USGS

Provide funding for the LDCM mission operations procurement

Implement a ground data processing capability

Implement a capability to ingest, archive, process, and distribute LDCM data

Following on-orbit check-out and acceptance, assume contract management and funding responsibility for the LDCM instrument and mission operations contracts

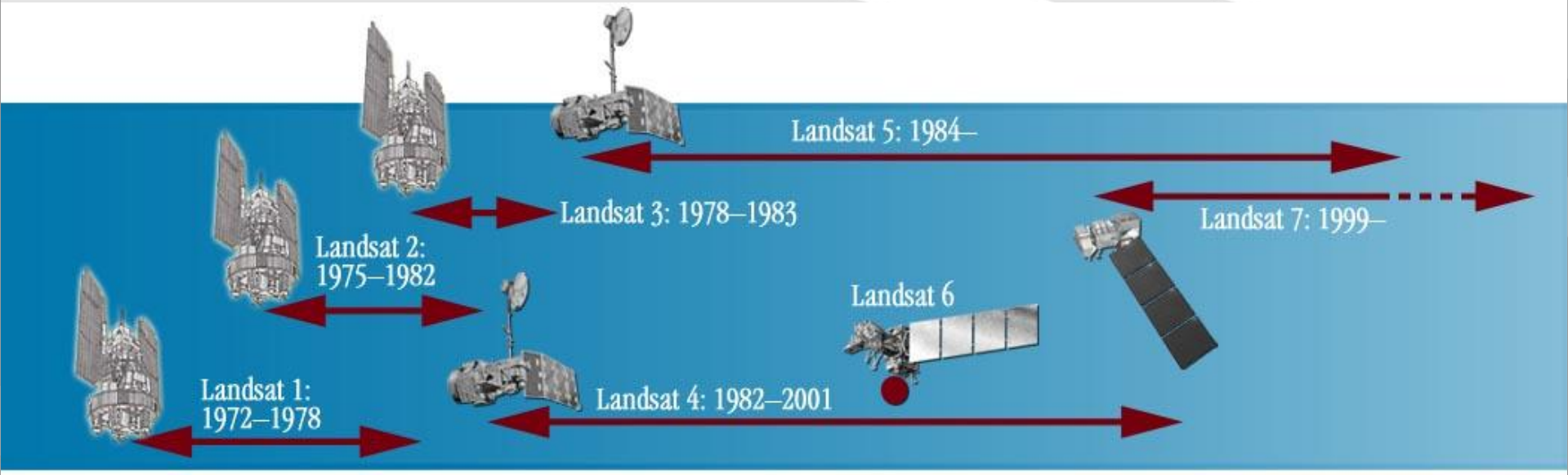
Provide long-term archive services

Convene a Landsat Mission Science Team

After on-orbit acceptance

- Lead the calibration, validation, and characterization
- Lead anomaly investigations

LANDSAT
30+ Years of Continuous Land Observations



1970 1975 1980 1985 1990 1995 2000 2005 2010

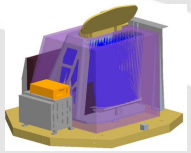
USGS NASA

Landsat Data Continuity Mission

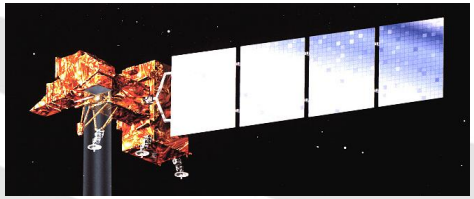
Mission Objectives

Provide continuity in the multi-decadal Landsat land surface observations to study, predict, and understand the consequences of land surface dynamics

- **Land cover/use change**
- **Human settlement and population**
- **Ecosystem dynamics**
- **Landscape scale carbon stocks**
- **Resource management/societal needs**



Operational Land Imager (OLI) procured by GSFC



Spacecraft Bus: Rapid Spacecraft Development Office Catalog procured by GSFC

Launch Vehicle procured under the Launch Service Task Order Contract at KSC

Ground Segment
Flight Operational S/W procured by GSFC for USGS
Mission Operations Center procured by USGS

Organizations

NASA GSFC Provides the LDCM Space Segment
NASA KSC Provides the launch vehicle
USGS Provides modifications to the Eros Data Center (EDC) and also coordinates the International Cooperator network.

USGS NASA

Introduction/Overview

LDCM is one of two measurements required of NASA by Public Law

Public Law 102-555, the Land Remote Sensing Policy Act of 1992 and Presidential Decision Directive/NSTC-3

- NASA and DOI/USGS established as Landsat Program Management

LDCM schedule is driven by need to minimize data gap with Landsat 7

NET July 2011 LRD and L-5/7 fuel depletion in 2010 = 6-12 month data gap

Schedule driver has resulted in “Aggressive” instrument schedule

- **40 mo vs. 60 mo typical**

USGS spearheading, with NASA co-chairing, the Landsat Data Gap Study Team investigation of alternatives to at least partially offset the data gap

- Technical investigations of data from India’s ResourceSat and China/Brazil CBERS satellites complete: Targeting Summer 2007 for “Data Gap Implementation” Report

LDCM will not have a thermal infrared capability

Cost estimate for thermal infrared exceeds available budget

If added to the development, an extension of the Data Gap will occur

Background
– continued-

Land Imaging Policy is now under consideration for ratification:

The Future of Land Imaging Interagency Working Group (FLI IWG) was convened by the National Science and Technology Council (NSTC) to address technical, financial, and managerial stability for operational land imaging (Marburger Dec 2005 memo)

FLI IWG convened from Feb-Nov 06 and performed systematic analysis of the state of U.S. civil land imaging.

The IWG has completed a report with recommended U.S. Policy change

- **"A PLAN FOR A NATIONAL LAND IMAGING PROGRAM"**
  - **published Aug 2007**

Acquisition Approach

Acquisition approach includes separate procurements for:

- instrument
- spacecraft
- launch vehicle and
- mission operations element (MOE)

NASA Goddard Space Flight Center (GSFC) will serve as the mission system integrator

Launch services provided by the NASA Launch Services at Kennedy Space Center (KSC)

Open competition for the instrument

- Contract awarded to Ball Aerospace and Technologies Corp – Jul 2007

Rapid Spacecraft Development Office (RSDO) contract procurement for the spacecraft

- RSDO spacecraft studies awarded Apr 2007 : Ball, Loral, General Dynamics, OSC

NASA in coordination with the USGS will compete the Mission Operations Element (MOE)

- To be released and awarded in early CY 2008.

LDCM will have a 5-year mission life

Following on-orbit verification, ownership will transfer to the USGS

USGS will operate the spacecraft and manage the data

LDCM Development Status

Acquisition includes separate procurements for:

Operational Land Imager (OLI) Instrument

- Final RFP released Jan 8, 2007
- Awarded to Ball Aerospace and Technologies Corp in Jul., 2007
- Award protested, GAO denied protest Nov. 9, 2007
- Instrument Systems Requirements Review held Nov. 6-7, 2007
- Successful Integrated Baseline Review held Nov. 13-15, 2007
- Mission Design Review to be held Mar., 2008

Spacecraft Procurement

- RSDO on-ramp opened Oct 25, 2006, closed Dec 15, 2006
- Four contractors (Ball, Loral, GD and OSC) selected for 4-month study phase (accommodation risk reduction) : Apr 30, 2007
- RFO to be released in the early Dec., 2007

LDCM Development Status
-continued-

Launch Vehicle

Launch services provided by the NASA Launch Services at Kennedy Space Center

Request for Offer issued March 30, 2007

Awarded to ULA for Atlas V 401 (Vandenberg launch) Oct., 2007

ATP NLT April 2009 (L-27)

Operations and Ground Systems

Mission Operations Element (Small Business Set Aside)

- PSM conducted Nov. 8, 2007
- Draft RFP schedule for release early Dec., 2007, final to be released Jan., 2008
- To be awarded Apr., 2008

Ground System Requirement Review held Sept. 26-27, 2007

USGS strategizing Contracting of development effort for Ground segment areas

- Data Processing and Archive Segment (DPAS)
- Science
- Flight Operations Segment (FOS)
- Infrastructure Support
- MOC location at EROS, Sioux Falls, SD

LDCM Draft Level – 1 Requirements

- Mission Lifetime: At least 5 years.
- Consumable Resources: At least 10 years of mission operation.
- Earth Spatial-Temporal Coverage: At least seasonal coverage of the global land mass.
- Landsat Data Consistency: Consistent with Landsat 7 Enhanced Thematic Mapper Plus (ETM+) data
  - in terms of acquisition geometry, calibration, coverage characteristics, spectral and spatial characteristics, output product quality and data availability
  - to allow comparisons for the detection and quantitative characterization of changes on the global land surface.
- Acquisition Geometry
  - Worldwide Reference System: Worldwide Reference System (WRS-2).
  - Equatorial Observation Time: 10:00 a.m. + or – 15 minutes.
  - Coverage Characteristics: At least once every 16 days.
  - Spectral Characteristics: (SEE TABLE)
  - Acquisition of thermal data is under investigation

LDCM Draft Level – 1 Requirements

Radiometric Performance: Sufficient to detect land cover change using historic Landsat data

Geometric Performance: Sufficient to detect land cover change using historic Landsat data

Scene Collection Rate: At least 400 WRS-2 scenes/24 hour period

Scene Generation and Distribution: 400 WRS-2 scenes/day

Public Access: Allow the Landsat user community and the general public to search the LDCM data archive and order LDCM data products on a nondiscriminatory basis per U.S. Code Title 15, Chapter 82.

Algorithm Release: Document and publicly release all algorithms

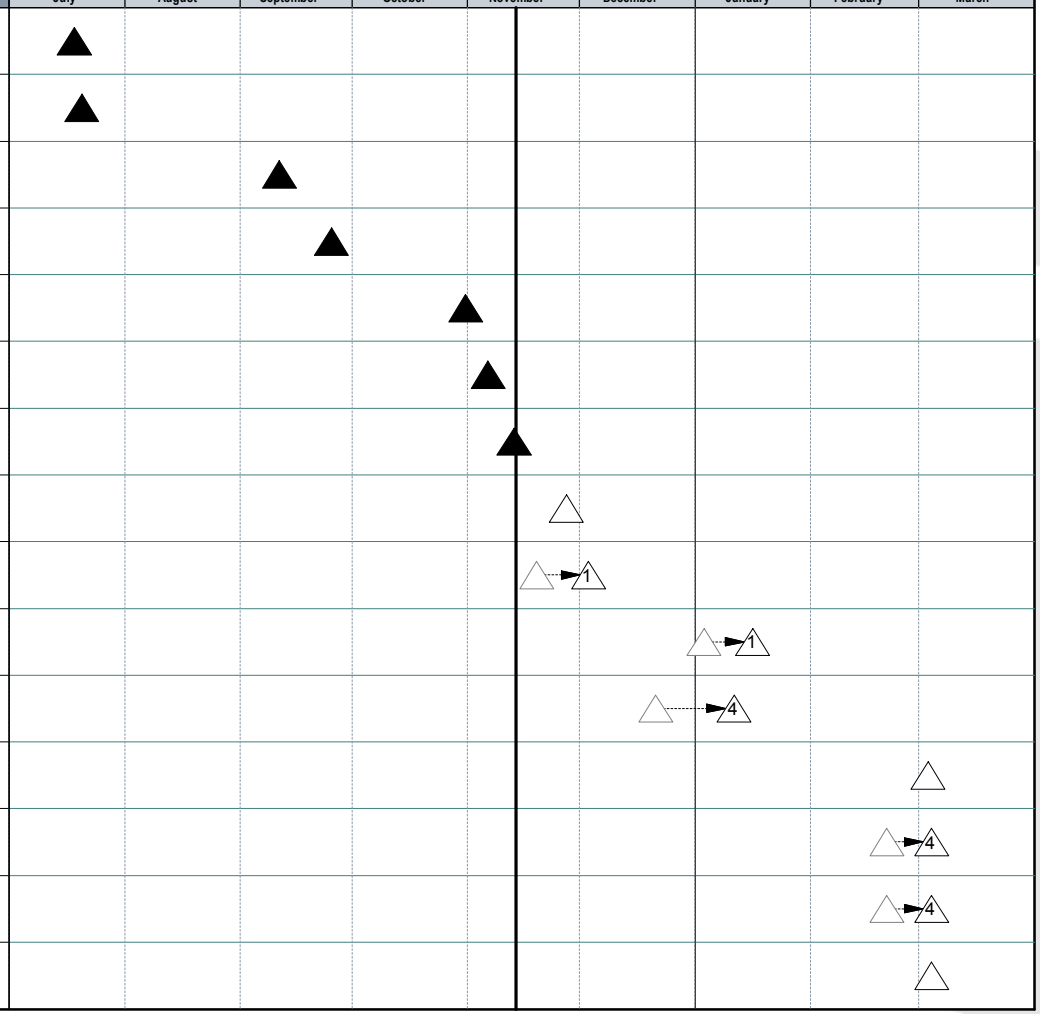
International Cooperator Support: Capable of transmitting to ICs

Science Team: Sustain a Landsat Science Team to provide guidance and address issues concerning the requirements for and applications of LDCM systems and data.

LDCM Development Status

Critical Milestones

	TASK	Start Date	End Date
1	Spacecraft Acceptance Review	7/18/07	7/18/07
2	OLI Instrument ATP	7/20/07	2/26/11
3	Launch Vehicle Selection Letter	9/11/07	6/20/11
4	Ground System SRR	9/25/07	9/25/07
5	S/C Bus Draft RFO Release	10/31/07	10/31/07
6	OLI Instrument SRR	11/6/07	11/6/07
7	OLI Instrument IBR	11/13/07	11/13/07
8	S/C Bus RFO Release	11/27/07	11/27/07
9	MOE Draft RFP Release	11/19/07	12/3/07
10	MOE Final RFP Release	1/3/08	1/16/08
11	S/C Bus RFO Response Due	12/21/07	1/11/08
12	LDCM Mission MDR/SRR	3/3/08	3/3/08
13	Spacecraft Bus Selection	2/21/08	3/4/08
14	Spacecraft ATP	2/21/08	3/4/08
15	OLI Instrument PDR	3/4/08	3/4/08

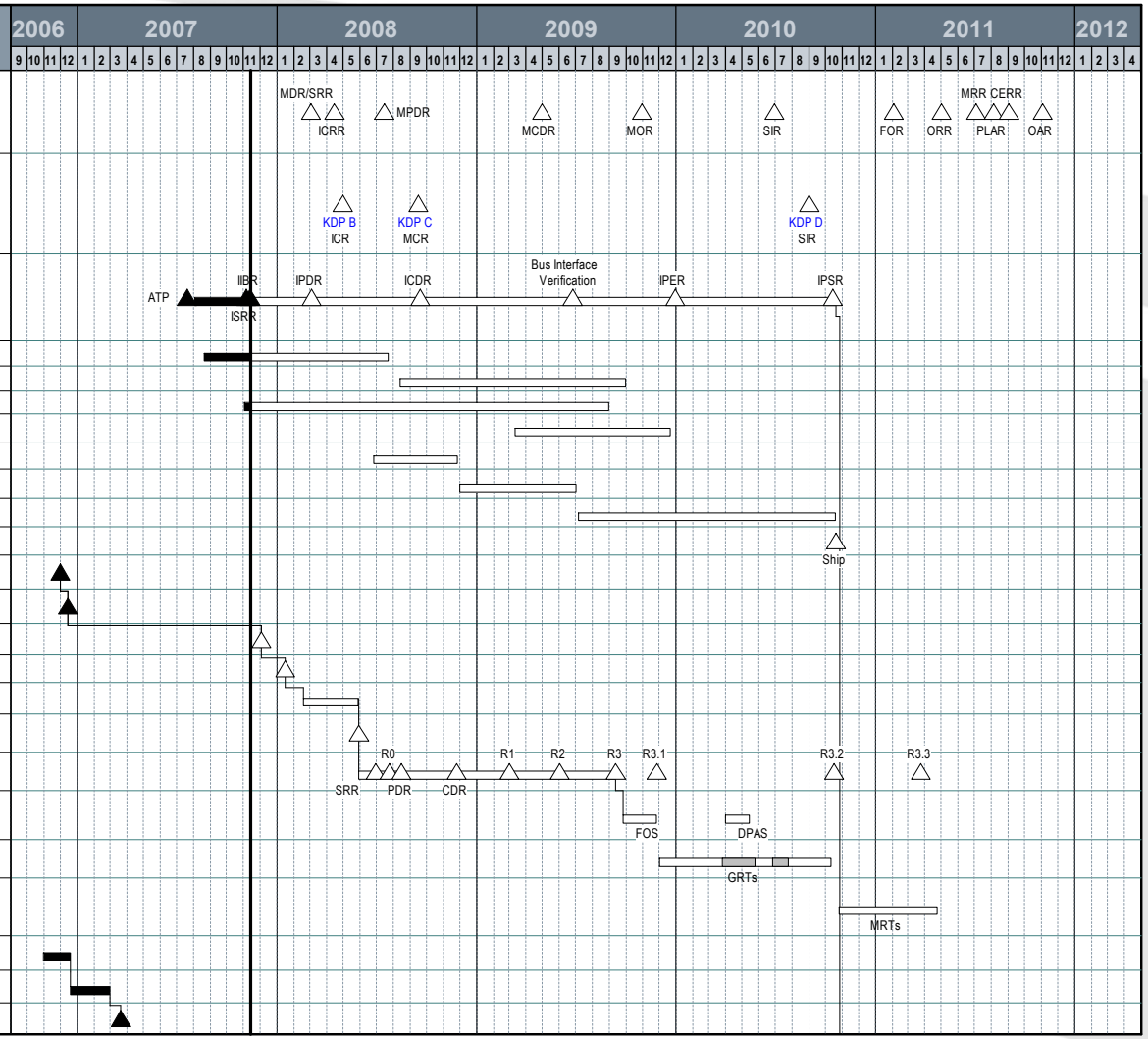


USGS NASA

LDCM Development Status

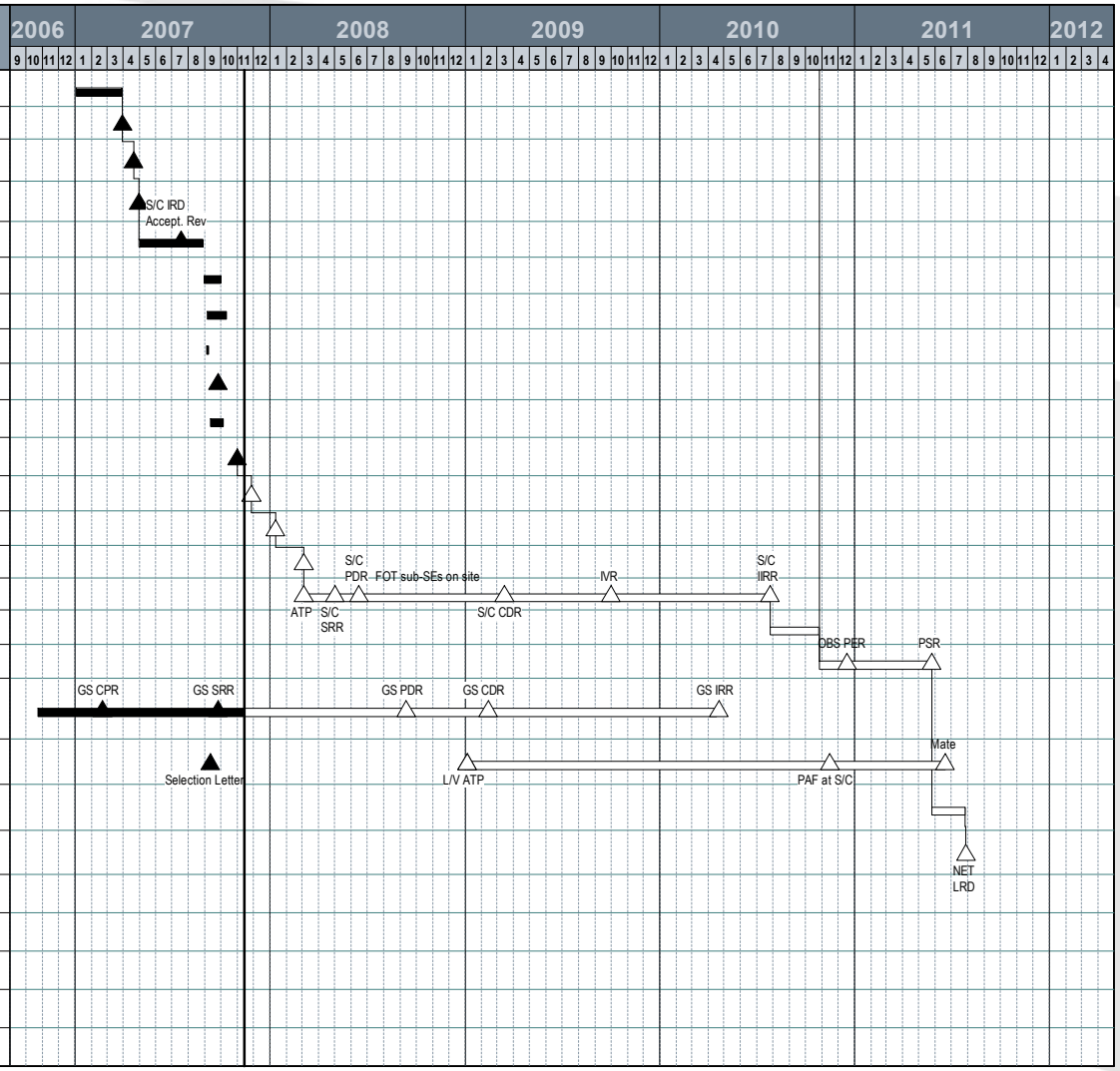
Draft Master Schedule

	TASK	Start Date	End Date
1	LDCM Mission Milestones	3/3/08	11/3/11
2	Key Decision Points (KDPs)	4/30/08	9/1/10
3	OLI Instrument Development	7/20/07	10/20/10
4	FPA Design	8/20/07	7/23/08
5	FPA Assy & Test	8/14/08	10/1/09
6	FPE Design, Assy & Test	11/2/07	8/31/09
7	FPS I & T	3/12/09	12/21/09
8	Optical Bench AI & T	6/26/08	11/26/08
9	Telescope AI & T	12/1/08	7/2/09
10	Instrument AI & T	7/6/09	10/20/10
11	Ship Instrument	10/20/10	10/20/10
12	MOE RFI Release	11/30/06	11/30/06
13	MOE RFI Responses Due	12/14/06	12/14/06
14	MOE Draft RFP Release	12/3/07	12/3/07
15	MOE Final RFP Release	1/16/08	1/16/08
16	MOE SEB	2/18/08	5/29/08
17	MOE Contract Award	5/30/08	5/30/08
18	MOE Development	5/30/08	3/25/11
19	GS Integration (w/MOC)	9/24/09	5/15/10
20	Ground Readiness Tests (GRTs)	12/1/09	10/12/10
21	Mission Readiness Tests (MRTs)	10/26/10	4/24/11
26	RSDO On-Ramp	10/30/06	12/18/06
27	RSDO On-Ramp Eval Complete	12/18/06	3/1/07
28	New RSDO Catalog	3/21/07	3/21/07



LDCM Development Status
Draft Master Schedule

	TASK	Start Date	End Date
29	S/C Bus Study RFO Preparation	1/3/07	3/30/07
30	S/C Bus Study RFO Release	3/30/07	3/30/07
31	S/C Bus Study RFO Responses Due	4/20/07	4/20/07
32	S/C Bus Study RFO Selection	4/30/07	4/30/07
33	Four Month Study	4/30/07	8/29/07
34	Study Extension	8/30/07	10/1/07
35	Finalize the DRC - 16	9/5/07	10/12/07
36	Conduct Subsystem Peer Reviews	9/4/07	9/8/07
37	Conduct a System Peer Review	9/25/07	9/25/07
38	Incorporate Changes From the Reviews	9/11/07	10/6/07
39	SC Bus Draft RFO Release	10/31/07	10/31/07
40	S/C Bus RFO Release	11/27/07	11/27/07
41	S/C Bus RFO Response Due	1/11/08	1/11/08
42	S/C Bus Selection	3/4/08	3/4/08
43	S/C Bus Development	3/4/08	7/26/10
44	S/C Bus Schedule Reserve	7/26/10	10/26/10
45	Observatory I & T	10/27/10	5/25/11
46	USGS Ground System Development	10/23/06	4/21/10
47	Launch Vehicle	9/11/07	6/20/11
48	Launch Site	5/26/11	7/27/11
49	LRD	7/28/11	7/28/11



Band Elimination Impact to Science

Elimination will impair the mitigation of current limitations to the systematic monitoring of the global land surface and coastal zones for change detection.

- **Cirrus Band Elimination**
  - **Precludes ability to detect thin cirrus cloud contamination of other spectral bands**
    - **Increases uncertainty of surface reflectance retrievals**
    - **Increases errors of commission (false positives) in change detection**
- **Coastal / Aerosol Band Elimination**
  - **Restricts ability to assess coastal zone and inland lake water quality; limits retrieval of chlorophyll, suspended matter, and colored dissolved organic matter concentrations.**
  - **Precludes aerosol retrievals leading to improved atmospheric correction**
- **Reduction of SNR, quantization, saturation levels**
  - **Reduce accuracy of land cover maps, land cover characterization, and change detection by reducing radiometric sensitivity and dynamic range**
  - **Inability to map bright surfaces: ice, snow, deserts inability to detect glacial flow velocities**

Potential Directed Instrument Manifests:

TIR

Top Level Science Requirements	
Thermal Bands, Center Wavelength	#10: 10.8 micron #11: 12.0 micron
Ground Sample Distance	<=120 m
Ground Swath	185 km
Absolute Radiometric Accuracy	260K - 330K: 2% 240K - 260K, 330K - 360K: 4%
Noise Equivalent Delta Temperature (NEDT)	0.4K at 300K 0.35K at 320K
Spatial Edge Response Slope	0.005 / meter Cross track 0.007 / meter Along track
Line of Sight Stability	27 arc seconds, 3σ
Field of View	15 degrees
Data Continuity	77 contiguous scenes (~ 34 minutes)
On Board Calibrator	Calibrate at 260K and 330K

Instrument Allocations	
Mass	200 kg
Power	250 W
Data Rate	<15 Mbps (TBD)
Data Storage	267 Gbits/day

Potential Directed Instrument Manifests:
TSIS

LASP involved to provide accommodation studies

Initiated development of mechanical and electrical ICDs, ops con, disturbance sources, support study, etc.

LASP has provided a no cost modification to the TSIS design

- Allows accommodation by any S/C vendor
- Reduced mass by 12kg
- Reduces jitter

TSIS added to RSDO Accommodation Study

Jitter, mass, power, T&C

Launch vehicle interface

Orbital debris mitigation

Field-of-view

Operations, calibration

Expanded Jitter Study

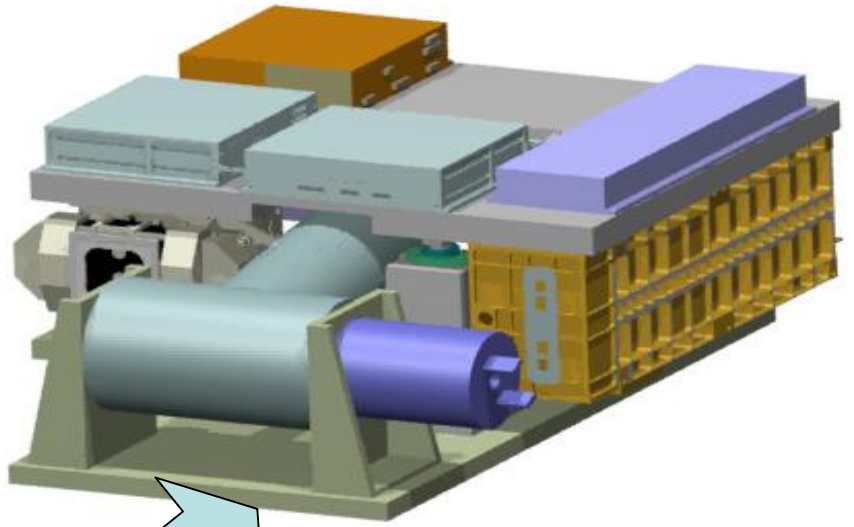
Jitter analysis being performed by GSFC, LASP, and S/C Vendors

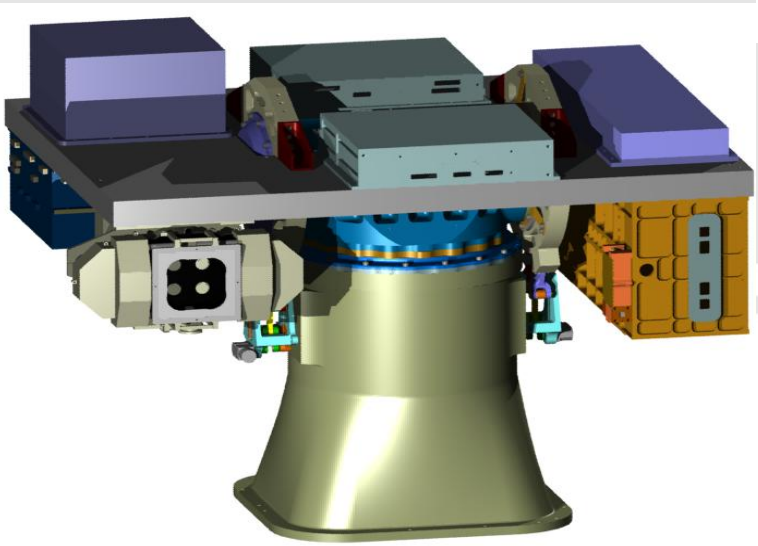
Manifest remains unauthorized and TBD

Potential Directed Instrument Manifests:
TSIS

TSIS ON LDCM

- 150 kg NTE mass estimate
- 0.9m x1.1m x0.4m





TSIS ON NPOESS

- 162 kg NTE mass estimate
- 1.1m x1.1m x1.1m

Potential Directed Instrument Manifests:
TIRS

Collaboration with International partners explored, but remains unfruitful

HQ chartered TIRS Risk Reduction Activity for summer 2006

Independent studies conducted from 2004 – 2006

- Led to selection of microbolometer as cost effective solution

Risk Reduction Activity completed the following tasks:

- Proof of feasibility of the technical concept with appropriate system technical and performance margins.
- Developed schedule and cost for the TIRS

System Definition Review held September 12, 2007

Risk Reduction effort stopped Sep., 2007

Final spacecraft RFO includes TIRS accommodation through design and as option for implementation

Manifest remains unauthorized and TBD

Potential Directed Instrument Manifests:
TIRS

Optical Sensor Unit (OSU)